Am7910
FSK MODEM
Advanced Micro Devices

PRODUCT SPECIFICATION

DISTINCTIVE CHARACTERISTICS

- Complete FSK MODEM in a 28-pin package (except line interface)
- Meets basic Bell 103/113, Bell 202, CCITT V.21, CCITT V.23 specifications (pin-programmable selection)
- No external filtering required
- All digital processing, including digital filters
- ADC/DAC on chip
- Auto-answer capability
- Local copy/test modes

GENERAL DESCRIPTION

The Am7910 is a single-chip asynchronous Frequency Shift Keying (FSK) voiceband modem. Operating at rates up to 300, 600 or 1200 bits per second, it is compatible with the applicable Bell and CCITT recommended standards for 103/113, 202, V.21 and V.23 type modems. Five mode control lines select a desired modem configuration.

Digital signal processsing techniques are employed in the Am7910 to perform all major functions such as modulation, demodulation and filtering. The Am7910 contains on-chip analog-to-digital and digital-to-analog converter circuits to minimize the external components in a system. This device includes the essential RS-232/CCITT V.24 terminal control signals with TTL levels.

Clocking can be generated by attaching a crystal to drive the internal crystal oscillator or by applying an external TTL-compatible clock signal.

A data access arrangement (DAA) or acoustic coupler must provide the phone line interface externally.

The Am7910 is fabricated using N-channel MOS technology in a 28-pin package. All the input and output signals (except the analog signals) are TTL compatible. Power supply requirements are ±5 volts with 600mW maximum power dissipation.

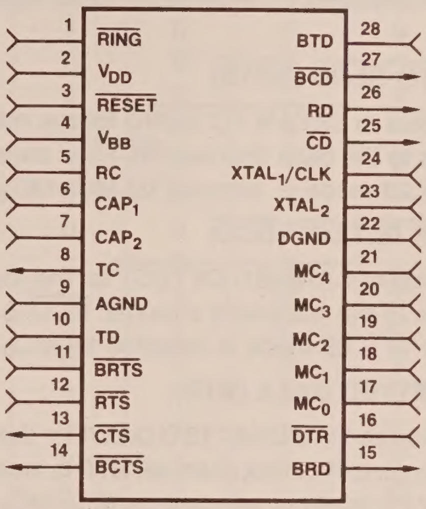

Figure 1. Am7910 Pinout

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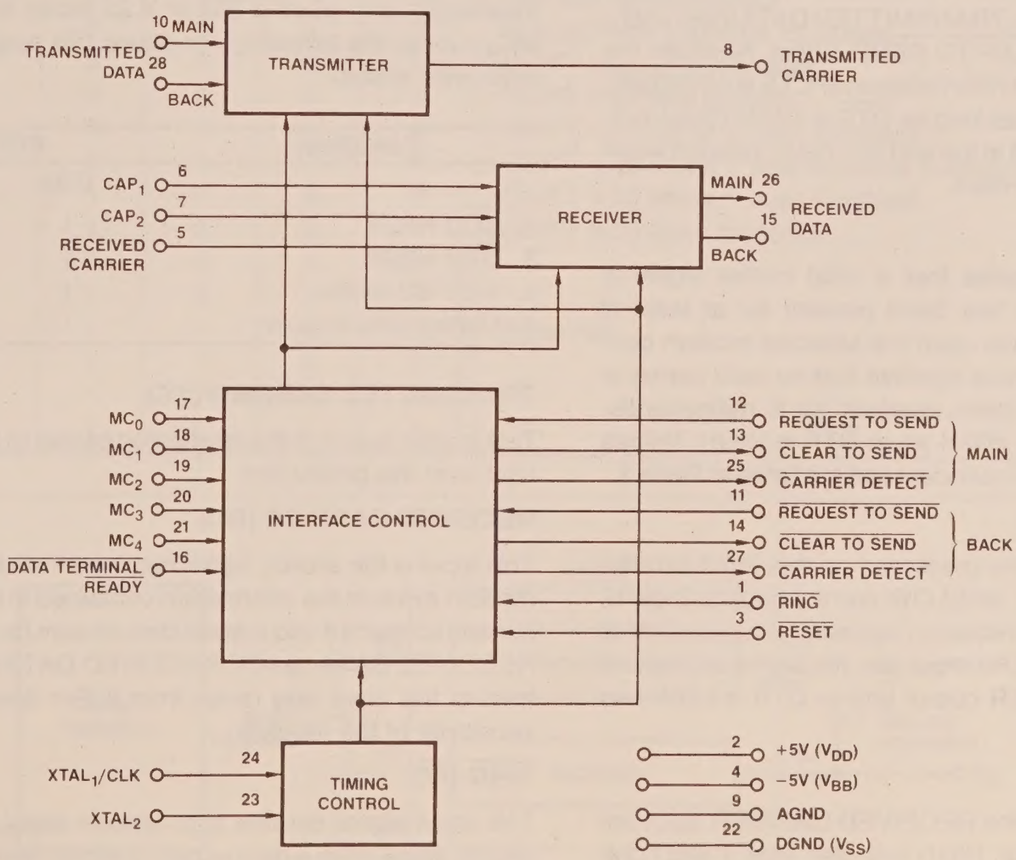

Figure 2. Am7910 Block Diagram

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INTERFACE SIGNAL DESCRIPTION

The logic symbol for the Am7910 is shown in Figure 1. A description of the interface pin signals follows.

MC_0-MC_4 (MODE CONTROL INPUTS)

These five inputs select one of thirty-two modem configurations according to the Bell or CCITT specifications listed in Table 1. Only 19 of these 32 modes are actually available to the user.

Modes 0-8 are the normal operation modes. The 1200 Baud modes can be selected with or without a compromise equalizer.

Modes 16-25 loop back the Am7910 transmitter to the Am7910 receiver. No internal connection is made. The user must externally connect the TRANSMITTED CARRIER pin (Figure 3) to the RECEIVED CARRIER pin if analog loopback is required. For digital loopback, external connection of the RECEIVED DATA and TRANSMITTED DATA is required. Whenever a mode in this group is selected, the effect is to set all transmit and receive filters to the same channel frequency band so that loopback can be performed.

Modes 9-15 and 26-31 are reserved and should not be used.

$\overline{\text{DATA TERMINAL READY}}$ ($\overline{\text{DTR}}$)

A LOW level on this input indicates the data terminal desires to send and/or receive data via the modem. This signal is gated with all other TTL inputs and outputs so that a low level enables all these signals as well as the internal control logic to function. A HIGH level disables all TTL I/O pins and the internal logic.

$\overline{\text{REQUEST TO SEND}}$ ($\overline{\text{RTS}}$)

A LOW level on this input instructs the modem to enter transmit mode. This input must remain LOW for the duration of data transmission. The signal has no effect if $\overline{\text{DATA TERMINAL READY}}$ is HIGH (disabled). A HIGH level on this input turns off the transmitter.

$\overline{\text{CLEAR TO SEND}}$ ($\overline{\text{CTS}}$)

This output goes LOW at the end of a delay initiated when $\overline{\text{REQUEST TO SEND}}$ goes LOW. Actual data to be transmitted should not be presented to the TRANSMITTED DATA input until a LOW is indicated on the $\overline{\text{CLEAR TO SEND}}$ output. Normally the user should force the TD input HIGH whenever $\overline{\text{CTS}}$ is off (HIGH). This signal never goes LOW as long as $\overline{\text{DTR}}$ is HIGH (disabled). $\overline{\text{CLEAR TO SEND}}$ goes HIGH at the end of a delay initiated when $\overline{\text{REQUEST TO SEND}}$ goes HIGH.

$\overline{\text{CARRIER DETECT}}$ ($\overline{\text{CD}}$)

A LOW on this output indicates that a valid carrier signal is present at the receiver and has been present for at least N milliseconds, where N depends upon the selected modem configuration. A HIGH on this output signifies that no valid carrier is being received and has not been received for K milliseconds. $\overline{\text{CARRIER DETECT}}$ remains HIGH when $\overline{\text{DTR}}$ is HIGH. Values for N and K are configuration dependent and are listed in Table 2.

TRANSMITTED DATA (TD)

Data bits to be transmitted are presented on this input serially; HIGH corresponds to logic 1 and LOW corresponds to logic 0. This data determines which frequency appears at any instant at the TRANSMITTED CARRIER output pin. No signal appears at the TRANSMITTED CARRIER output unless $\overline{\text{DTR}}$ is LOW and $\overline{\text{RTS}}$ is LOW.

RECEIVED DATA (RD)

Data bits demodulated from the RECEIVED CARRIER input are available serially at this output; HIGH indicates logic 1 and LOW indicates logic 0. Under the following conditions this output is forced to logic 1 because the data may be invalid:

1. When $\overline{\text{CARRIER DETECT}}$ is HIGH
2. During the internal squelch delay at half-duplex line turn around (202/V.23 modes only)
3. During soft carrier turnoff at half-duplex line turn around (202 mode only)
4. When $\overline{\text{DTR}}$ is HIGH
5. When $\overline{\text{BRTS}}$ ON and $\overline{\text{RTS}}$ OFF in V.23/202 modes only.
6. During auto-answer sequence.

$\overline{\text{BACK REQUEST TO SEND}}$ ($\overline{\text{BRTS}}$)

Since the 1200 BPS modem configurations, Bell 202 and CCITT V.23, permit only half duplex operation over two-wire lines, a low baud rate "backward" channel is provided for transmission from the main channel receiver to the main channel transmitter. This input signal ($\overline{\text{BRTS}}$) is identical to $\overline{\text{REQUEST TO SEND}}$ for the main channel, except it belongs to the backward channel. Note that since the Am7910 contains a single transmitter, $\overline{\text{RTS}}$ and $\overline{\text{BRTS}}$ should not be asserted simultaneously. If this situation occurs, $\overline{\text{RTS}}$ will dominate. $\overline{\text{BRTS}}$ is meaningful only when a 202 or V.23 mode is selected by MC_0-MC_4. In all other modes it is ignored.

$\overline{\text{BACK CLEAR TO SEND}}$ ($\overline{\text{BCTS}}$)

This line is identical to $\overline{\text{CLEAR TO SEND}}$ for the main channel, except it belongs to the back channel. $\overline{\text{BCTS}}$ is meaningful only when a 202 or V.23 mode is selected by MC_0-MC_4.

$\overline{\text{BACK CARRIER DETECT}}$ ($\overline{\text{BCD}}$)

This line is identical to $\overline{\text{CARRIER DETECT}}$ for the main channel, except it belongs to the backward channel. $\overline{\text{BCD}}$ is meaningful only when a 202 or V.23 mode is selected by MC_0-MC_4.

BACK TRANSMITTED DATA (BTD)

This line is identical to TRANSMITTED DATA for the main channel, except it belongs to the back channel. BTD is meaningful only when a 202 or V.23 mode is selected by MC_0-MC_4.

BACK RECEIVED DATA (BRD)

This line is identical to RECEIVED DATA (except clamping) for the main channel, except it belongs to the back channel. BRD is meaningful only when a 202 or V.23 mode is selected by MC_0-MC_4. Under the following conditions this output is forced to the logic level shown:

Condition	BRD Level	
	V.23	201
1. $\overline{\text{BCD}}$ HIGH	1	0
2. $\overline{\text{DTR}}$ HIGH	1	1
3. V.21/103 mode	1	1
4. During auto-answer	1	1

TRANSMITTED CARRIER (TC)

This analog output is the modulated carrier to be conditioned and sent over the phone line.

RECEIVED CARRIER (RC)

This input is the analog signal received from the phone line. The modem extracts the information contained in this modulated carrier and converts it into a serial data stream for presentation at the RECEIVED DATA (BACK RECEIVED DATA) output. The signal level at this input may range from 0dBm down to −48dBm, the sensitivity of the receiver.

$\overline{\text{RING}}$ ($\overline{\text{RI}}$)

This input signal permits auto-answer capability by detecting a ringing signal from a data access arrangement. If a ringing signal is detected ($\overline{\text{RING}}$ LOW) and $\overline{\text{DTR}}$ is LOW, the modem begins a sequence to generate an answer tone at the TC output.

$XTAL_1$, $XTAL_2$

Master timing of the modem is provided by either a crystal connected to these two inputs or a TTL level clock inserted into $XTAL_1$. The value of the crystal or the TTL clock frequency must be 2.4576 MHz ±1%.

V_{DD}

+5 volt power supply. (±5%)

V_{BB}

−5 volt power supply. (±5%)

DGND (V_{SS})

Digital signal ground pin.

AGND

Analog signal ground pin (for TRANSMITTED CARRIER and RECEIVED CARRIER).

CAP_1, CAP_2

Connection points of external capacitor/resistor required for proper operation of on-chip analog-to-digital converter.

Recommended values are: C = 400pF, R = 7.2KΩ

$\overline{\text{RESET}}$

This input signal is for a reset circuit which operates in either of two modes. It automatically resets when power is applied to the device, or it can be activated by application of an external active low TTL pulse.

TABLE 1

MC_4	MC_3	MC_2	MC_1	MC_0	
0	0	0	0	0	Bell 103 Originate 300bps full duplex
0	0	0	0	1	Bell 103 Answer 300bps full duplex
0	0	0	1	0	Bell 202 1200bps half duplex
0	0	0	1	1	Bell 202 with equalizer 1200bps half duplex
0	0	1	0	0	CCITT V.21 Orig 300bps full duplex
0	0	1	0	1	CCITT V.21 Ans 300bps full duplex
0	0	1	1	0	CCITT V.23 Mode 2 1200bps half duplex
0	0	1	1	1	CCITT V.23 Mode 2 with equalizer 1200bps half duplex
0	1	0	0	0	CCITT V.23 Mode 1 600bps half duplex
0	1	0	0	1	Reserved
0	1	0	1	0	
0	1	0	1	1	
0	1	1	0	0	
0	1	1	0	1	
0	1	1	1	0	
0	1	1	1	1	
1	0	0	0	0	Bell 103 Orig loopback
1	0	0	0	1	Bell 103 Ans loopback
1	0	0	1	0	Bell 202 Main loopback
1	0	0	1	1	Bell 202 with equalizer loopback
1	0	1	0	0	CCITT V.21 Orig loopback
1	0	1	0	1	CCITT V.21 Ans loopack
1	0	1	1	0	CCITT V.23 Mode 2 main loopback
1	0	1	1	1	CCITT V.23 Mode 2 with equalizer loopback
1	1	0	0	0	CCITT V.23 Mode 1 main loopback
1	1	0	0	1	CCITT V.23 Back loopback
1	1	0	1	0	Reserved
1	1	0	1	1	
1	1	1	0	0	
1	1	1	0	1	
1	1	1	1	0	
1	1	1	1	1	

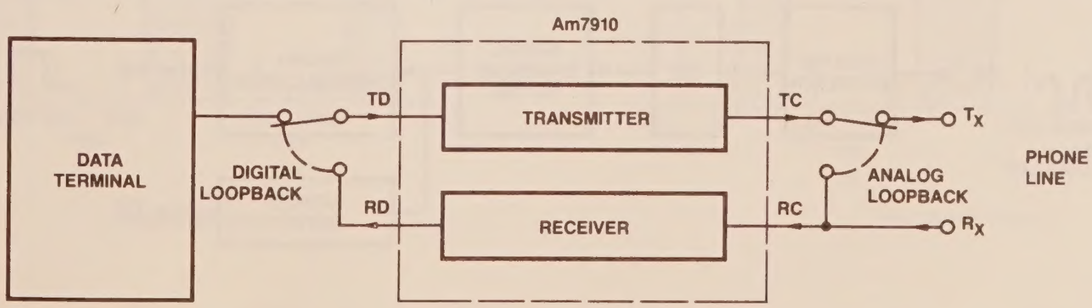

Figure 3. Loopback Configurations

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THEORY OF OPERATION

The Am7910 MODEM consists of three main sections, shown in the block diagram of Figure 2 – Transmitter, Receiver, and Interface Control.

TRANSMITTER (Modulator)

The transmitter, shown in Figure 4, receives binary digital data from a source such as a UART and converts the data to an analog signal using frequency shift keying (FSK) modulation. This analog signal is applied to the phone line through a DAA or acoustic coupler. FSK is a modulation technique which encodes one bit per baud. A logic one applied to the TRANSMITTED DATA (TD) input causes a sine wave at a given frequency to appear at the analog TRANSMITTED CARRIER (TC) output. A logic zero applied to input TD causes a sine wave of a different frequency to appear at the TC ouput. As the data at the TD input switches between logical one and zero, the TC output switches between the two frequencies. In the Am7910 this switching between frequencies is phase continuous. The frequencies themselves are digitally synthesized sine functions.

The frequencies for each modem configuration available in the Am7910 are listed in Table 2.

The process of switching between two frequencies as in FSK generates energy at many more frequencies than the two used in the modulation. All the transmitted information can be recovered from a frequency band B Hz wide, where B is the bit rate or maximum rate of change of the digital data at the TD input. This band is centered about a frequency, f_C,

where $f_C = f_1 + (f_2 - f_1)/2$

(f_1 = lower of two FSK frequencies)

(f_2 = higher of two FSK frequencies)

In addition to this primary information band, there exist side bands containing redundant information. It is desirable to attenuate these bands for two reasons:

1. The phone companies have specifications on the amount of energy allowed in certain frequency bands on the line.
2. If two independent information channels are present simultaneously on the line (e.g. 300 bps full duplex or 1200 bps half duplex with back), the redundant transmitter components may fall in the frequency band of the local receiver channel and interfere with detection. In the Am7910 these redundant and undesirable components are attenuated by digital bandpass filters.

Following the digital bandpass filters, the filtered FSK signal is converted to an analog signal by an on-chip DAC operating at a high sample rate. This analog FSK signal is finally smoothed by a simple on-chip analog low pass filter.

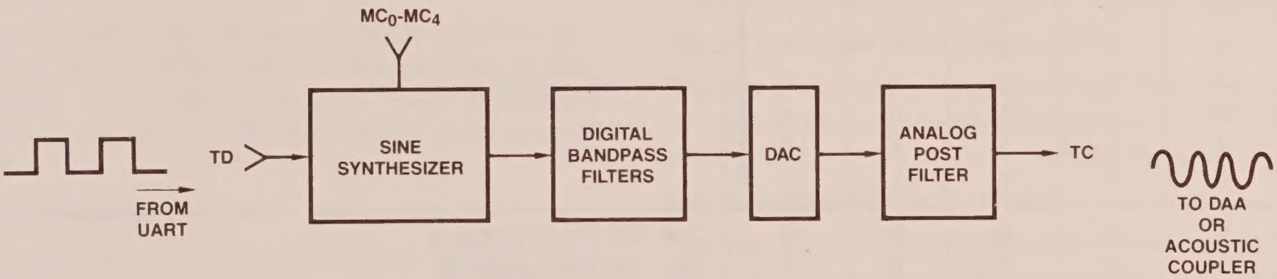

Figure 4. Transmitter Block Diagram

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RECEIVER (Demodulator)

A simplified block diagram of the Am7910 FSK receiver is shown in Figure 5. Data transmitted from a remote site modem over the phone line is an FSK-modulated analog carrier. This carrier is applied to the RECEIVED CARRIER (RC) pin via a DAA or acoustic coupler. The first stage of the demodulator is a simple on-chip analog low pass anti-alias filter. The output of this is converted into digital form and filtered by digital bandpass filters to improve the signal to noise ratio and reject other independent channel frequencies associated with the phone line in the case of full duplex configuration. The bandpass filtered output is digitally demodulated to recover the binary data. A carrier detect signal is also digitally extracted from the received line carrier to indicate valid data.

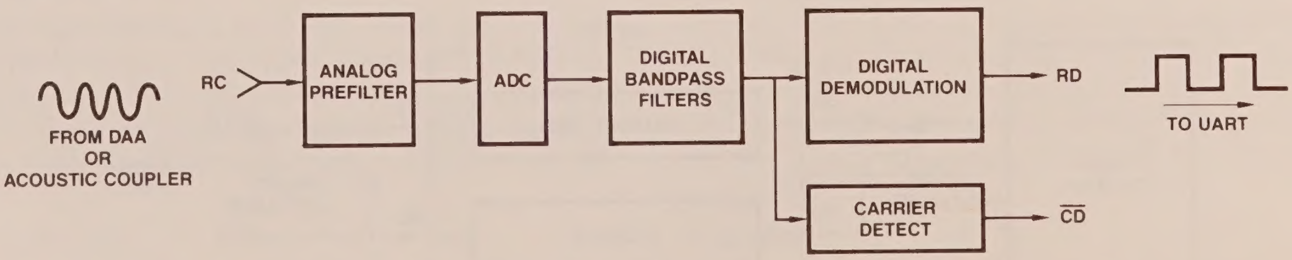

Figure 5. Receiver Block Diagram

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INTERFACE CONTROL

This section controls the handshaking between the modem and the local terminal. It consists primarily of delay generation counters, two state machines for controlling transmission and reception, and mode control decode logic for selecting proper transmit frequencies and transmit and receive filters according to the selected modem type. Inputs and outputs from this section are as follows:

- $\overline{\text{REQUEST TO SEND}}$ (Main and Back)
- $\overline{\text{CLEAR TO SEND}}$ (Main and Back)
- $\overline{\text{CARRIER DETECT}}$ (Main and Back)
- $\overline{\text{RING}}$
- MCO-MC4
- $\overline{\text{DATA TERMINAL READY}}$

Internal logic clamps protocol signals to different levels under certain conditions (e.g., initial conditions).

When Bell 103/113 and V.21 modem configurations are selected, the back channel signals are non-functional.

Figures 8 and 9 depict the sequencing of the two state machines. State machine 1 implements main or back channel transmission and the auto-answer sequence. State machine 2 implements reception on main or back channel.

The state machine powers on to the state labelled INITIAL CONDITIONS. Handshake signals are set to or assumed to be the levels listed in Table 3. The machine then waits for $\overline{\text{DATA TERMINAL READY (DTR)}}$ to be turned on. Whenever $\overline{\text{DTR}}$ is turned to the OFF state from an ON condition, each state machine and external signals return to the initial conditions within 25 microseconds. After $\overline{\text{DTR}}$ is turned ON the Am7910 becomes operational as a modem and the state machines proceed as depicted in the flowcharts.

The definitions of the terms Full Duplex and Half Duplex used in these flowcharts are depicted below (Figs. 6 and 7). "Full Duplex" applies to all 103/113, V.21 modes. "Half Duplex" applies to 202 and V.23, both forward and backward channel.

Full Duplex: Data can be transmitted and received simultaneously at a rate of 300 baud. Two independent 300Hz channels are frequency multiplexed into the 3000Hz bandwidth of the phone line. The Am7910 configurations for the Bell 103/113 and CCITT V.21 can be operated full duplex.

Half Duplex: In half duplex with back channel, the modem may transmit at 1200/600 baud and receive at 5/75 baud. Alternatively it may transmit at 5/75 baud and receive at 1200/600 baud. Examples are Bell 202 and CCITT V.23.

TABLE 3
Initial Conditions

Data Terminal Ready ($\overline{\text{DTR}}$)	OFF
Request to Send ($\overline{\text{RTS}}$)	OFF
Clear to Send ($\overline{\text{CTS}}$)	OFF
Transmitted Data (TD)	Ignored
Back Channel Request to Send ($\overline{\text{BRTS}}$)	OFF
Back Channel Clear to Send ($\overline{\text{BCTS}}$)	OFF
Back Channel Transmitted Data (BTD)	Ignored
Ring ($\overline{\text{RI}}$)	OFF
Carrier Detect ($\overline{\text{CD}}$)	OFF
Received Data (RD)	MARK
Back Channel Carrier Detect ($\overline{\text{BCD}}$)	OFF
Back Channel Received Data (BRD)	MARK

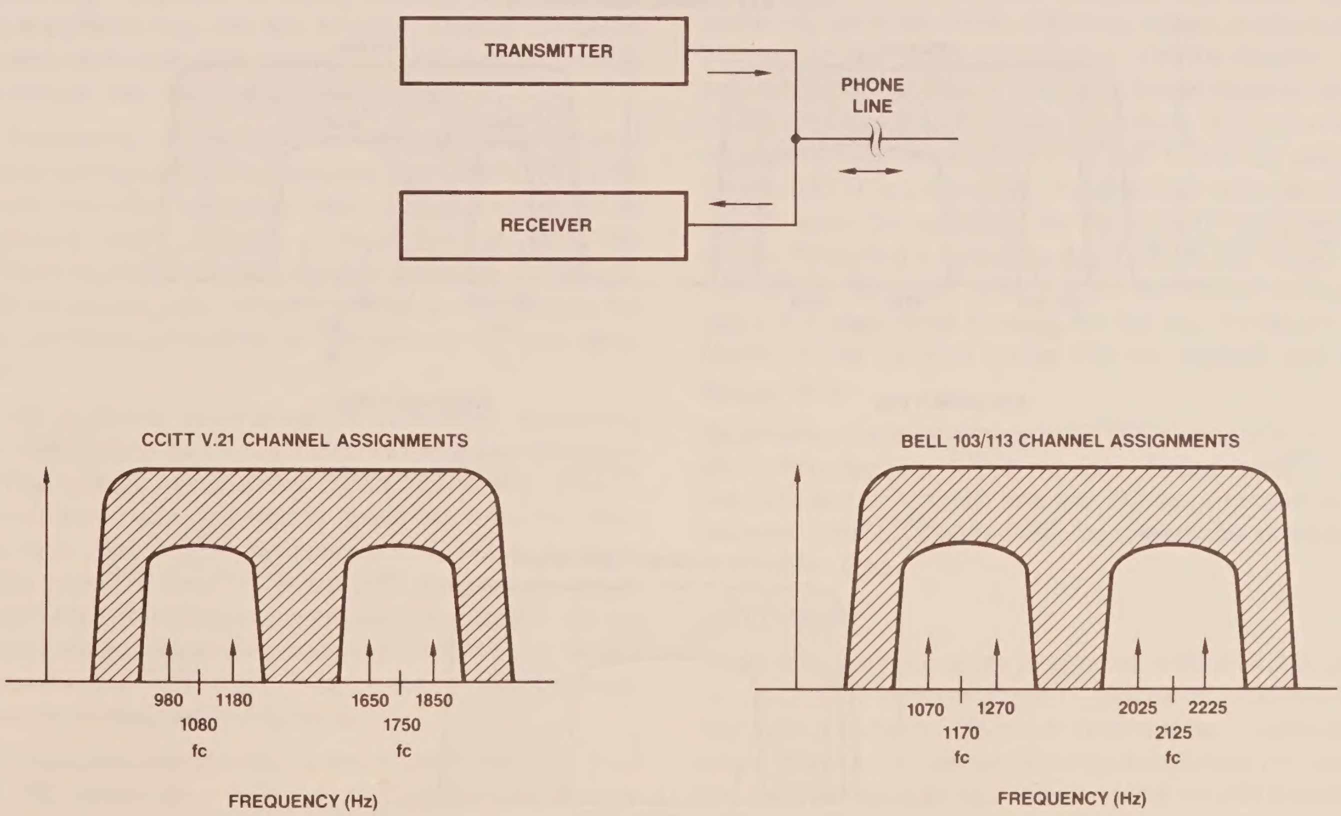

Figure 6. Full Duplex

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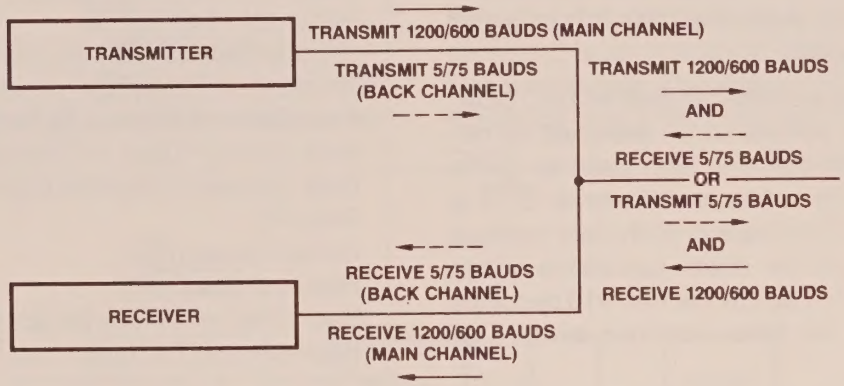
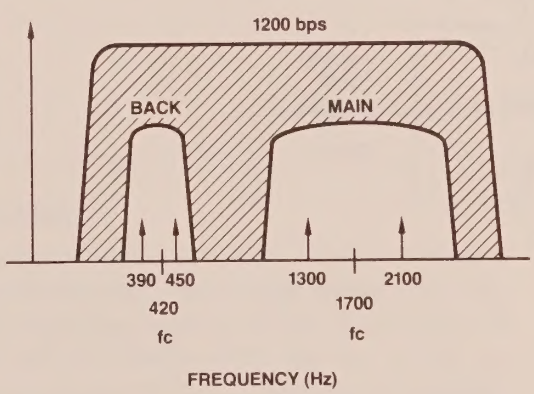
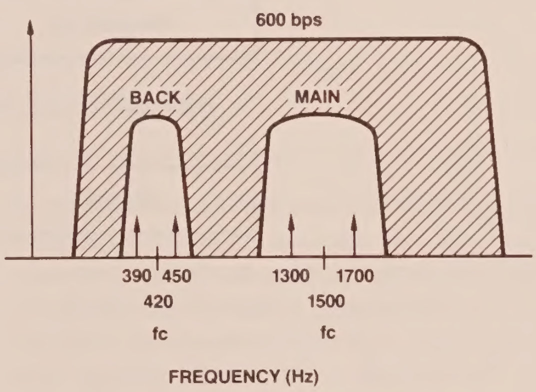
TABLE 2

Modem	Baud Rate (BPS)	Duplex	Transmit Frequency		Receive Frequency		Answer Tone Freq Hz	t_{RCON} ms ±.3%
			Space Hz	Mark Hz	Space Hz	Mark Hz		
Bell 103 Orig	300	Full	1070	1270	2025	2225	–	208.3
Bell 103 Ans	300	Full	2025	2225	1070	1270	2225	208.3
CCITT V.21 Orig	300	Full	1180	980	1850	1650	–	400
CCITT V.21 Ans	300	Full	1850	1650	1180	980	2100	400
CCITT V.23 Mode 1	600	Half	1700	1300	1700	1300	2100	208.3
CCITT V.23 Mode 2	1200	Half	2100	1300	2100	1300	2100	208.3
CCITT V.23 Mode 2 Equalized	1200	Half	2100	1300	2100	1300	2100	208.3
Bell 202	1200	Half	2200	1200	2200	1200	2025	183.3
Bell 202 Equalized	1200	Half	2200	1200	2200	1200	2025	183.3
CCITT V.23 Back	75	–	450	390	450	390	–	–
Bell 202 Back	5	–	387	0	387	0	–	–



CCITT V.23 CHANNEL ASSIGNMENTS





BELL 202 CHANNEL ASSIGNMENTS

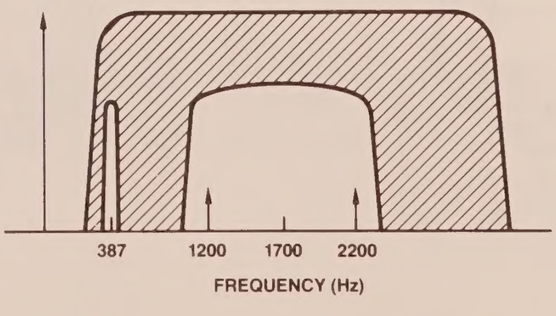


Figure 7. Half Duplex

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TABLE 2 (Cont.)

t_{RCOFF} ms ±.25%	t_{BRCON} ms ±.3%	t_{BRCOFF} ms ±.25%	t_{CDON} ms ±1.2%	t_{CDOFF} ms ±2.4%	t_{BCDON} ms ±.31%	t_{BCDOFF} ms ±.31%	t_{AT} s ±.41%	t_{SIL} s ±.41%	t_{SQ} ms ±3.3%	t_{ST} ms ±2.3%
0.5	–	–	100	20.8	–	–	1.9	1.3	–	–
0.5	–	–	100	20.8	–	–	1.9	1.3	–	–
0.5	–	–	300	20.8	–	–	3.0	1.9	–	–
0.5	–	–	300	20.8	–	–	3.0	1.9	–	–
0.5	–	–	10.4	5.2	–	–	3.0	1.9	156.3	–
0.5	–	–	10.4	5.2	–	–	3.0	1.9	156.3	–
0.5	–	–	10.4	5.2	–	–	3.0	1.9	156.3	
0.5	–	–	20.8	10.4	–	–	1.9	1.3	156.3	24
0.5	–	–	20.8	10.4	–	–	1.9	1.3	156.3	24
–	82.3	0.5	–	–	41.7	41.7	–	–	–	–
–	20.8	0.5	–	–	41.7	41.7	–	–	–	–

Frequency Tolerance is less than ±1.0 Hz

CALL ESTABLISHMENT

Before two modems can exchange data, an electrical connection through the phone system must be established. Although it may assist in call establishment, a modem typically does not play a major role. A call may be originated manually or automatically and it may be answered manually or automatically.

Manual Calling – Manual calling is performed by a person who dials the number, waits for an answer , then places the calling modem into data transmission mode.

Automatic Calling – Automatic calling is typically performed by an automatic calling unit (ACU) which generates the appropriate dialing pulse or dual-tone sequence required to call the remote (called) modem. The ACU also has the ability to detect an answer tone from the called modem and place the calling modem into data transmission mode.

Manual Answering – Manual answering is performed by a person who hears the phone ring, lifts the receiver, causes the called modem to send an answer tone to the calling modem, and places the called modem into data transmission mode.

Automatic Answering – Automatic answering is performed by a called modem with a data access arrangement (DAA). The DAA provides a ringing signal which can instruct the called modem to take the phone circuit off-hook (corresponds to lifting the receiver). Next the called modem sends out silence on the line, followed by an answer tone. When this tone is detected by the calling modem, the connection is considered to have been established.

The Am7910 provides assistance for automatic answering through the $\overline{\text{RING}}$ signal as follows. Observe the upper right-hand portion of Figure 8(a). Assume that $\overline{\text{DATA TERMINAL READY}}$ ($\overline{\text{DTR}}$) has recently been asserted to cause exit from the initial conditions. Note that if $\overline{\text{DTR}}$ remains OFF, $\overline{\text{RING}}$ is ignored. Assume also that $\overline{\text{RTS}}$ and $\overline{\text{BRTS}}$ are OFF and that the mode control lines (MCO-MC4) select a normal modem configuration, not a loopback mode. Automatic answering is initiated by receipt of a LOW level at the $\overline{\text{RING}}$ input, causing entrance to the auto-answer sequence depicted in Figure 8(c).

The Am7910 outputs silence (0.0 volts) at its TRANSMITTED CARRIER (TC) output for a time, t_{SIL}, followed by the answer tone for a time, t_{AT}. The $\overline{\text{CARRIER DETECT}}$ ($\overline{\text{CD}}$) pin is clamped OFF and the RECEIVED DATA (RD) signal is therefore clamped to a MARK (HIGH) during the auto-answer sequence. Upon completion of the answer tone, $\overline{\text{CD}}$ is released. If the mode lines (MCO-MC4) select a 202 or V.23 mode, the transmit filters are set to the forward channel and the receive filters are set to the back channel during the auto answer sequence.

At the end of the auto-answer sequence, return is made to point A in the loop at the upper right-hand portion of Figure 8(a). Note that since the answer flag has been set, the auto-answer sequence cannot be entered again unless $\overline{\text{DTR}}$ is first turned OFF, then ON. At this point the phone line connection has been established and data transmission or reception may begin.

The $\overline{\text{RING}}$ input may be activated from a conditioned DAA Ring Indicator output for automatic answering or it may be activated by a switch for manual answering. Tying $\overline{\text{RING}}$ HIGH will disable the auto-answer function of the Am7910.

DATA TRANSMISSION

Full Duplex

Following call establishment, full duplex data transmission can be started by either the called or calling modem. In other words, if the connection has been established and the modem is looping through point A in Figure 8(a), it no longer matters which is the called and which is the calling modem. Data transmission is initiated by asserting $\overline{\text{REQUEST TO SEND}}$ ($\overline{\text{RTS}}$). At this time the TRANSMITTED DATA (TD) input will be released and a modulated carrier can appear at the TRANSMITTED CARRIER (TC) output. Following a delay, t_{RCON}, $\overline{\text{CLEAR TO SEND}}$ ($\overline{\text{CTS}}$) will turn ON. At this time, data may be transmitted through the TD input. It is a common protocol for the user to always present a MARK at the TD input before RTS is asserted and during the t_{RCON} delay.

Data transmission continues until $\overline{\text{RTS}}$ is turned OFF. Following a short delay, t_{RCOFF}, $\overline{\text{CTS}}$ turns OFF. As soon as $\overline{\text{RTS}}$ goes OFF, the TD input is ignored and the TC output is set to 0.0 volts (silence). After $\overline{\text{CTS}}$ turns OFF, the state machine returns to point A in Figure 8(a).

Half Duplex

When a half duplex mode is selected (202 or V.23), data transmission can be either on the main channel at 1200/600 baud or on the back channel at 5/75 baud. In normal half duplex operation a single modem is either transmitting on the main and receiving on the back channel or vice versa. In the Am7910 control of the transmitter and receiver filters to the proper channel is performed by $\overline{\text{RTS}}$. When $\overline{\text{RTS}}$ is asserted, the transmitter filters and synthesizer are set to transmit on the main channel; the receiver filters are set to receive on the back channel. Therefore, whenever $\overline{\text{RTS}}$ is on, $\overline{\text{BRTS}}$ should not be asserted since the

transmitter cannot be used for the back channel. When RTS is OFF and a half duplex mode is selected, the transmitter filters and synthesizer are set to the back channel; the receiver filters are set to the main channel. If RTS and BRTS are asserted simultaneously, RTS will take precedence. However, if BRTS is asserted before RTS and the back channel data transmission sequence has been entered (Figure 8(b)), RTS will be ignored until BRTS is turned OFF.

The state machine sequences for main and back channel transmission differ slightly and are depicted in Figure 8. Assume the state machine is idling through point A in Figure 8(a).

Main Channel

This transmission sequence is entered if a 202 or V.23 mode is selected and RTS is asserted. Since the receiver is now forced to the back channel, the RECEIVED DATA (RD) signal is clamped to a MARK; and the CARRIER DETECT signal is clamped OFF. The TRANSMITTED DATA input (TD) is released and a carrier appears at the TRANSMITTED CARRIER output which follows the MARK/SPACE applied to TD. RTS turning ON initiates a delay, t_{RCON}, at the end of which the CLEAR TO SEND (CTS) output goes LOW. When CTS goes LOW data may be transmitted through input TD. Data transmission continues until RTS is turned OFF. At this time several events are initiated. First a delay, t_{RCOFF}, is initiated at the end of which CTS turns OFF. The TD input is ignored as soon as RTS goes OFF. If a 202 mode is selected, a soft turn-off tone appears at the TC output for a time, t_{STO}, followed by silence (0.0 volts). For both 202 and V.23 modes a squelch period, t_{SQ}, is initiated when RTS goes OFF. During this period the CD output is clamped OFF, forcing the RD output to a MARK condition. The squelch period begins as soon as RTS goes OFF and thus overlaps both t_{RCOFF} and t_{STO}. At the end of the squelch period, the state machine returns to the idle loop at point A in Figure 8(a).

The reasons for squelch and soft-turnoff are as follows:

Soft Turn-Off: When RTS is turned OFF at the end of a message, transients occur which may cause spurious space signals to be received at a remote modem. During soft turn-off the modem transmits a soft carrier frequency for a period, t_{STO}, after RTS is turned OFF. This results in a steady MARK on the RECEIVED DATA (RD) line of the remote modem.

Squelch: The local receiver must be turned OFF after RTS is OFF, until the start of carrier detect, so that line transients are not demodulated. The process of disabling the receiver after RTS is turned OFF is called squelching.

Back Channel

This transmission sequence, shown in Figure 8(b), is entered if a 202 or V.23 mode is selected, RTS is OFF, and BRTS is asserted. The BACK CARRIER DETECT (BCD) output is forced OFF and the BACK RECEIVED DATA (BRD) output is clamped to a MARK. The BACK TRANSMITTED DATA input (BTD) is released and a carrier appears at the TC output which follows the MARK/SPACE applied to BTD. Turning ON BRTS initiates a delay, t_{BRCON}, at the end of which the BACK CLEAR TO SEND (BCTS) output goes LOW. When BCTS goes LOW data may be transmitted through input BTD. Data transmission continues until BRTS is turned OFF. The input BTD is immediately ignored and the TC output is silenced (set to 0.0 volts). Following a short delay, t_{BRCOFF}, the output BCTS goes OFF. The signals BCD and BRD are released and the state machine returns to idle at point A of Figure 8(a).

DATA RECEPTION

Data reception is controlled by state machine 2 and depicted in Figure 9. At power on the machine enters initial conditions and remains there until DTR is asserted. It then loops until either CARRIER DETECT(CD) or BACK CARRIER DETECT (BCD) occurs.

Full Duplex

In full duplex data reception, CARRIER DETECT may appear at any time after the phone connection has been established. Reception is independent of transmission. When the receiver detects a valid carrier for at least a time, t_{CDON}, the output CD is turned ON, the RECEIVED DATA (RD) output is released, and valid data can be obtained at RD. Data is received until the receiver detects loss of carrier for at least a time, t_{CDOFF}. At this time the CD output is turned OFF and RD is clamped to a MARK. The state machine returns to the idle loop at point E.

Half Duplex

As discussed in the data transmission section above, when a half duplex mode has been selected, the signal RTS controls whether the main channel is transmitting or receiving. The back channel can only do the opposite from the main. If RTS is OFF, then CARRIER DETECT may be asserted and the data reception sequence is identical to that dicussed above for full duplex reception. As long as RTS remains OFF, BACK CARRIER DETECT will never be asserted. If RTS is ON, then CARRIER DETECT will never be asserted. Instead the receiver will look for a valid carrier in the back channel frequency band. If a valid carrier exists for at least a time, t_{BCDON}, the output BACK CARRIER DETECT (BCD) is turned ON, the BACK RECEIVED DATA (BRD) output is released and valid data can be obtained at BRD. Data is received until the receiver detects loss of back channel received signal for at least time, t_{BCDOFF}. At this time the BCD output is turned OFF. Data output, BRD, is clamped to a MARK if a V.23 mode is selected and a SPACE if a 202 mode is selected. The state machine returns to the idle loop at point E.

LOOPBACK

Ten modes exist to allow both analog and digital loopback for each modem specification met by the Am7910. When a loopback mode is selected, the signal processing (filters, etc.) for both the transmitter and receiver is set to process the same channel or frequency band. This allows the analog output, TRANSMITTED CARRIER, and the analog input, RECEIVED CARRIER, to be connected for local analog loopback. Alternatively the digital data signals, TD and RD or BTD and BRD, can be connected externally, allowing a remote modem to test the local modem with its digital data signals looped back.

When a loopback mode is selected, the state machine sequences are altered slightly. First, auto-answer is disabled. Second, if a half duplex loopback mode is selected (202 or V.23), the local CARRIER DETECT/BCD is not forced OFF when RTS/BRTS is asserted.

Note that the V.23 Back Channel loopback mode allows the Am7910 to be used as an independent transmitter and receiver in an application with two 2400 bps DPSK modems on a four-wire line. The 202 and V.23 main loopback modes allow use in a 4-wire configuration at 1200 bps.

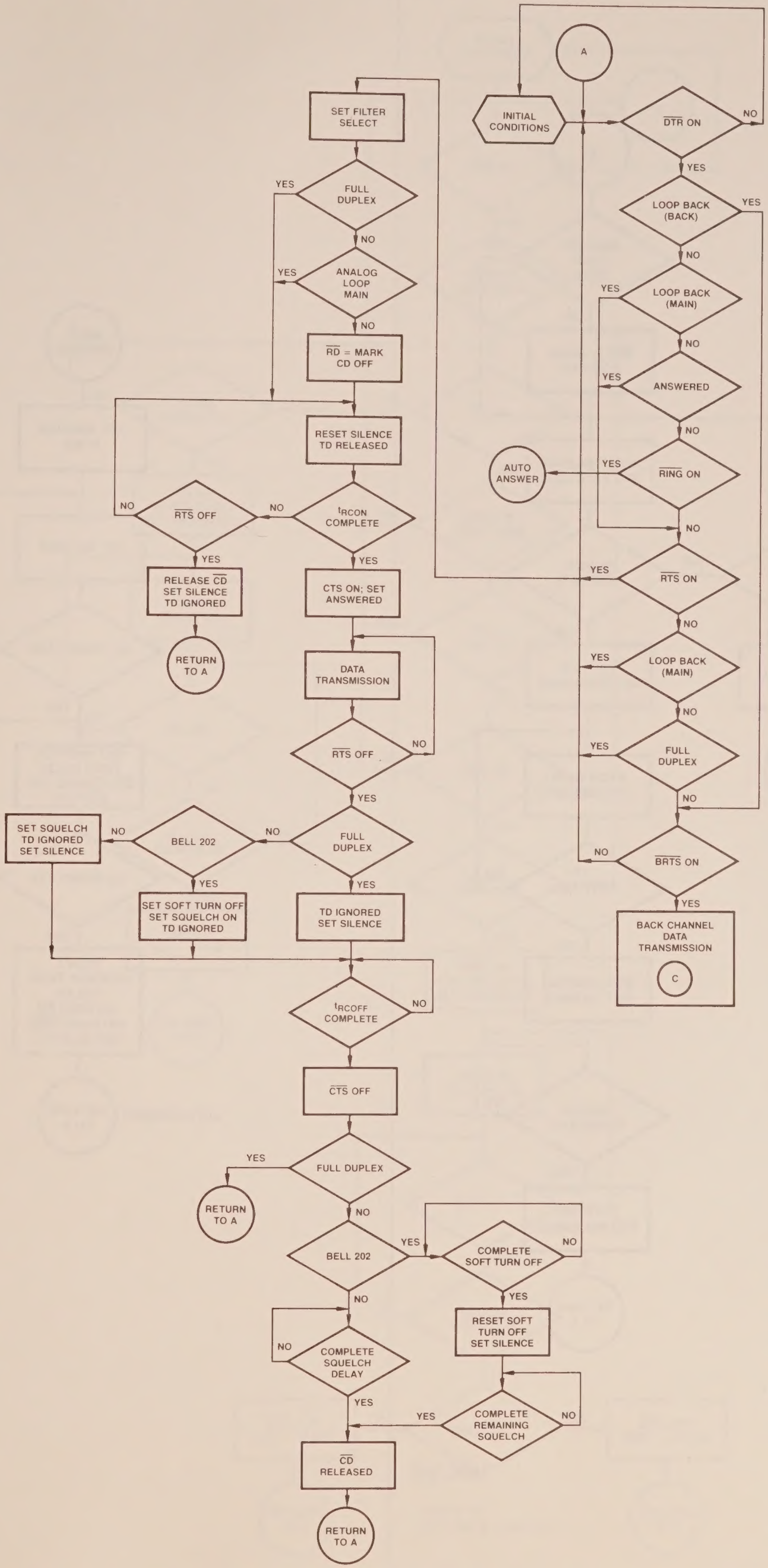


Figure 8(a). Transmit Main Channel

MMC-041

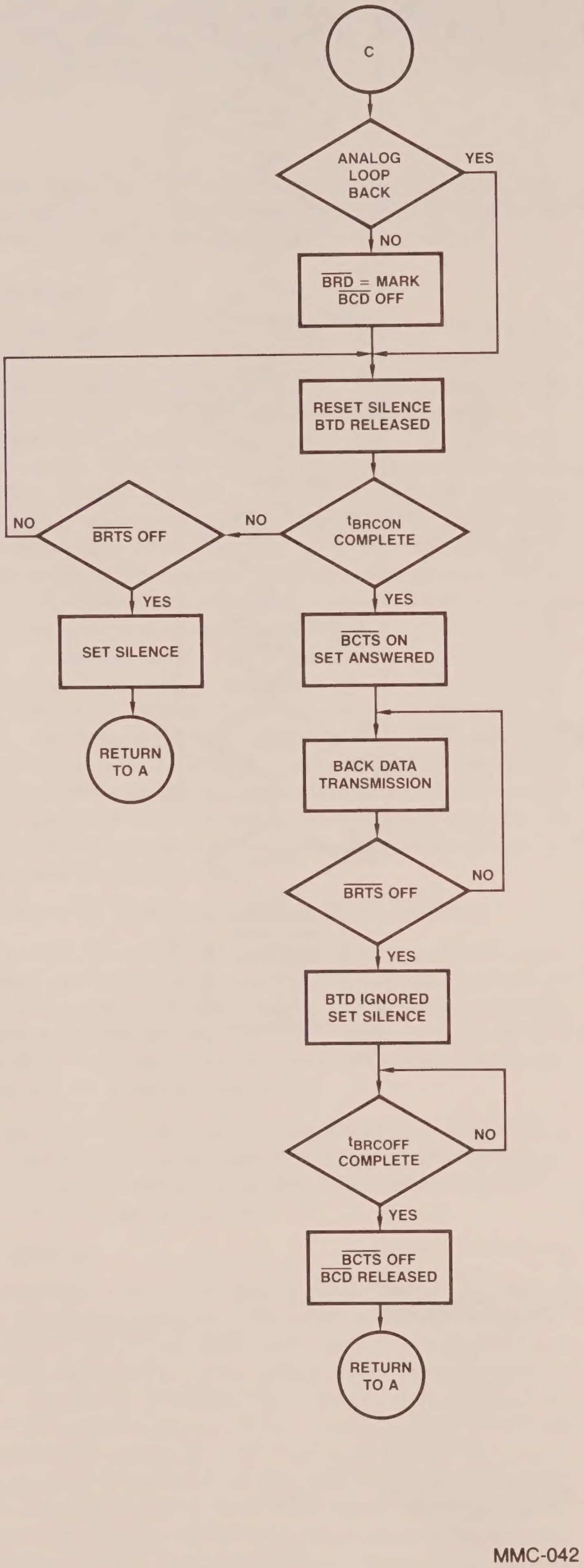


Figure 8(b). Transmit Back Channel

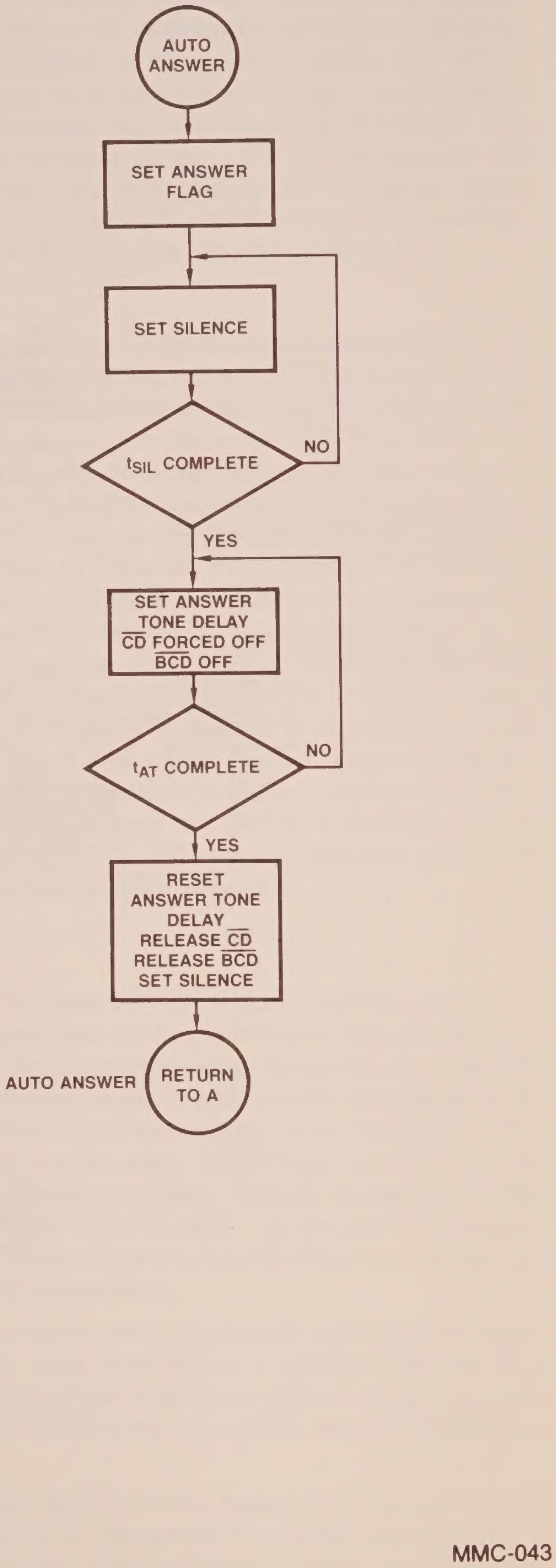


Figure 8(c). Auto Answer

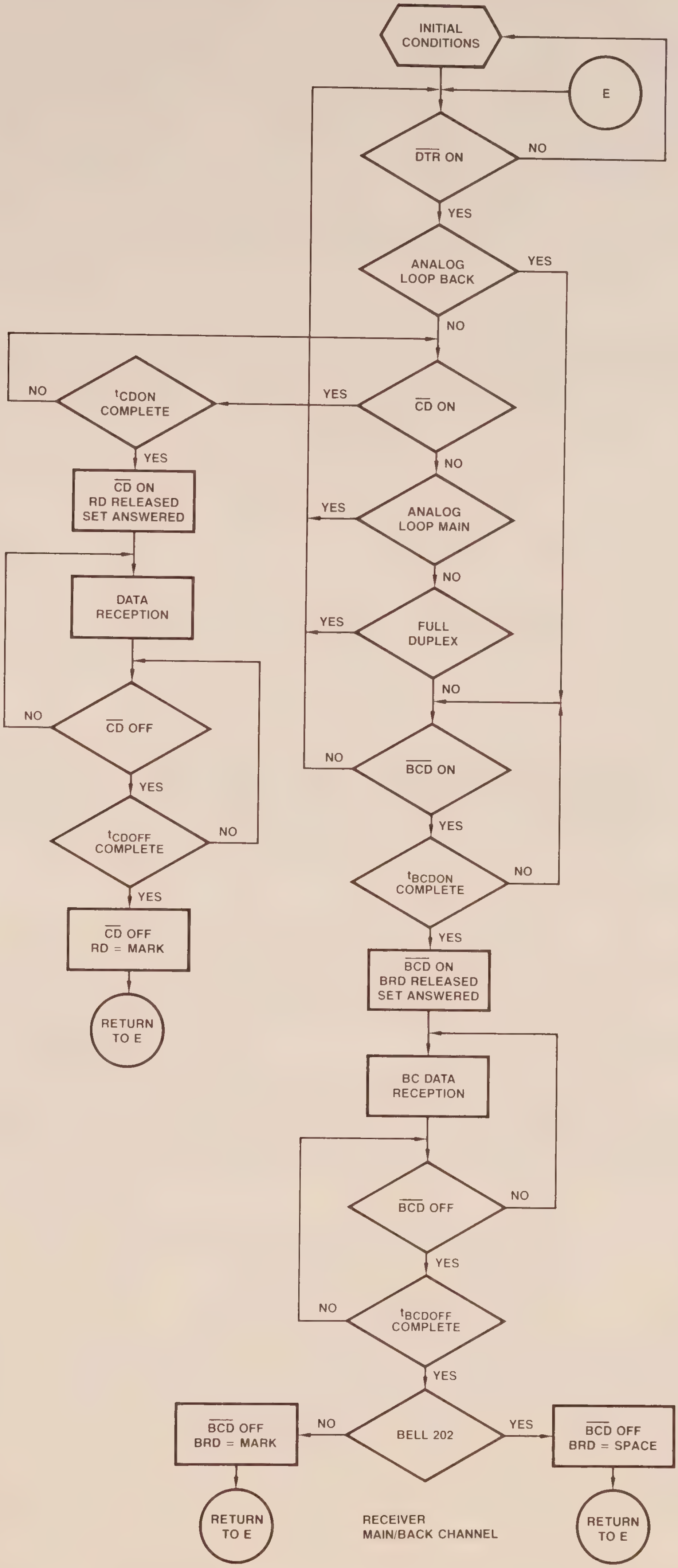


Figure 9. Receiver Main/Back Channel

MMC-044

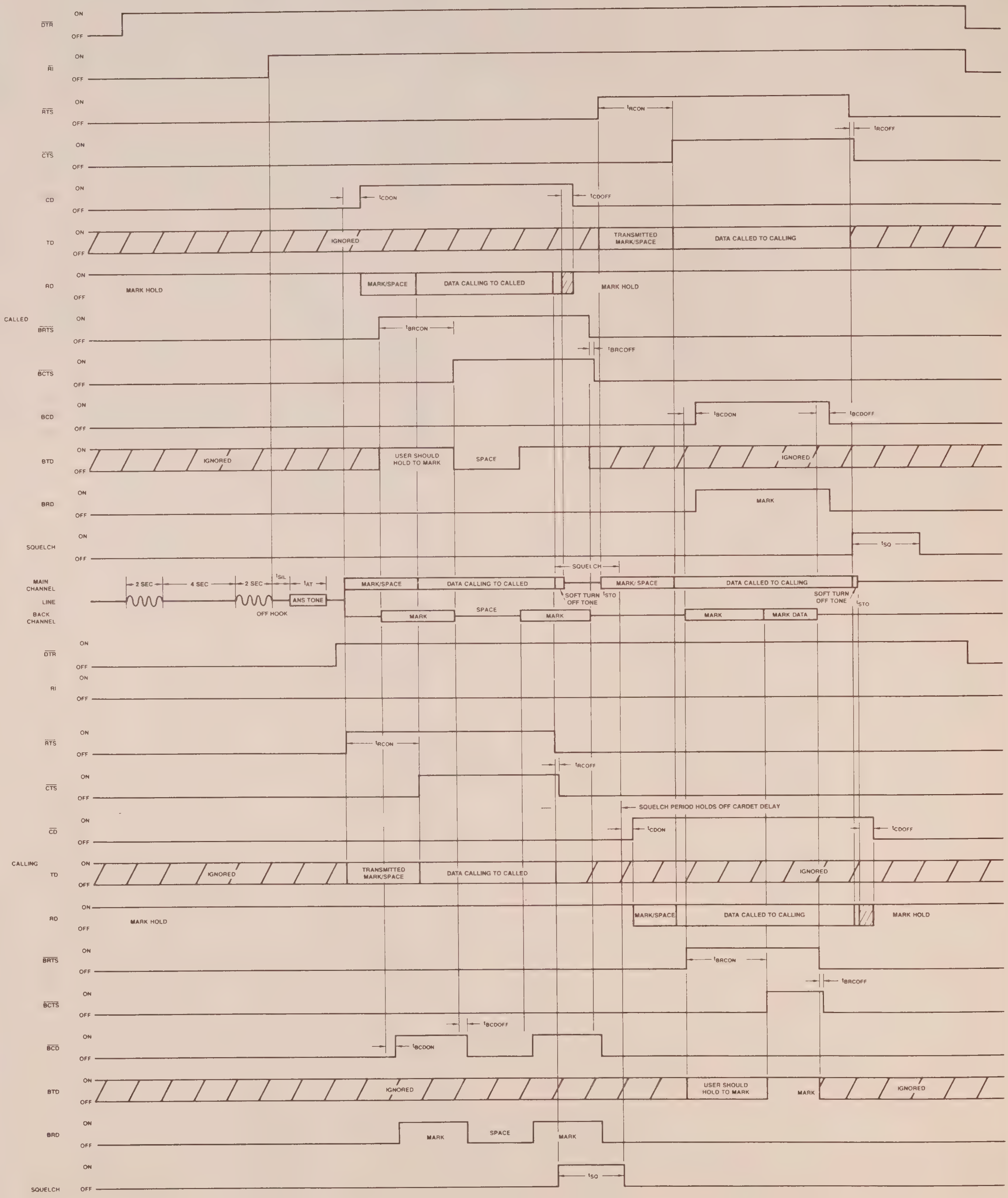


Figure 10. BELL 202 handshake timing

MMC-045

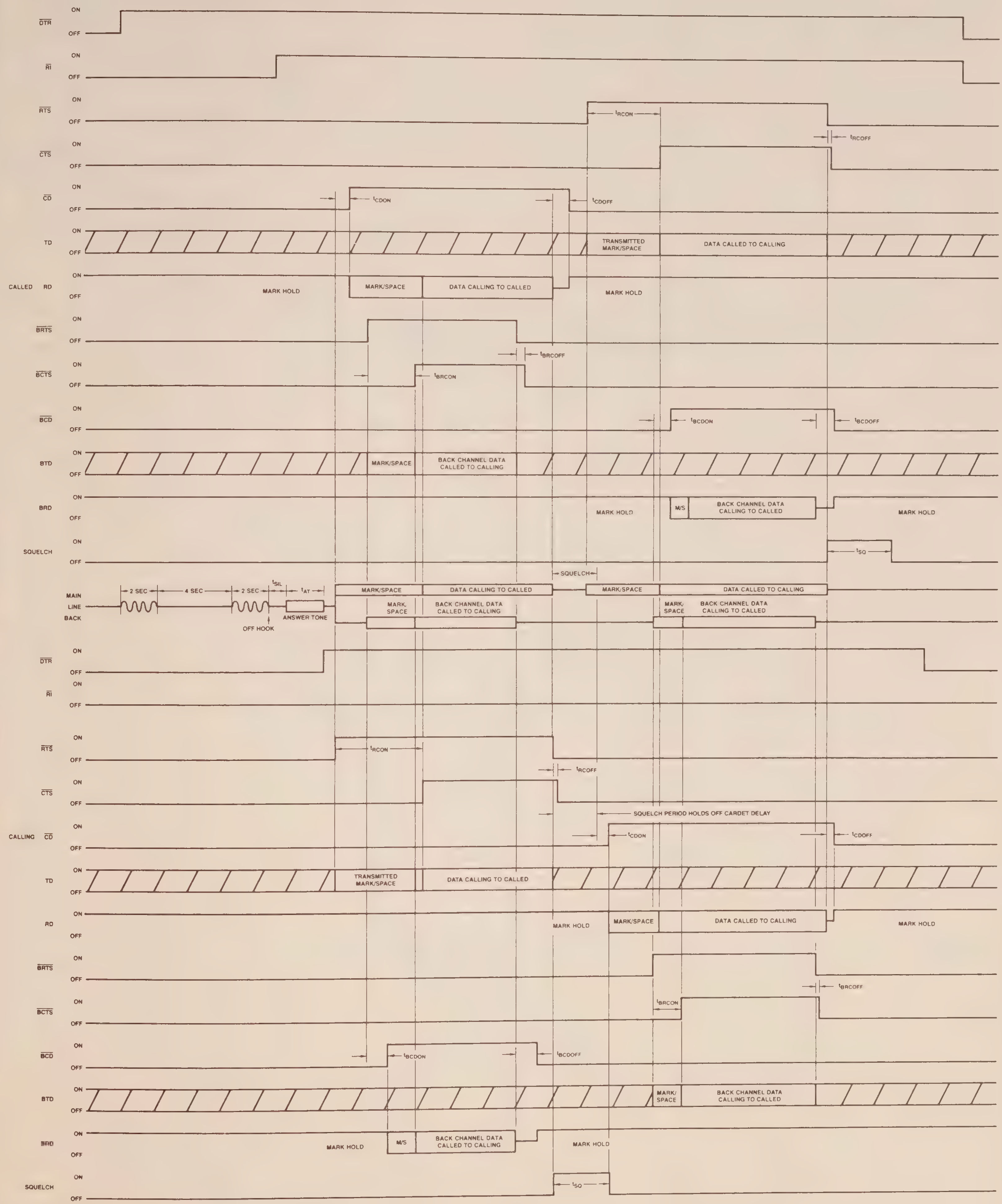


Figure 11. CCITT V.23 handshake timing

MMC-046

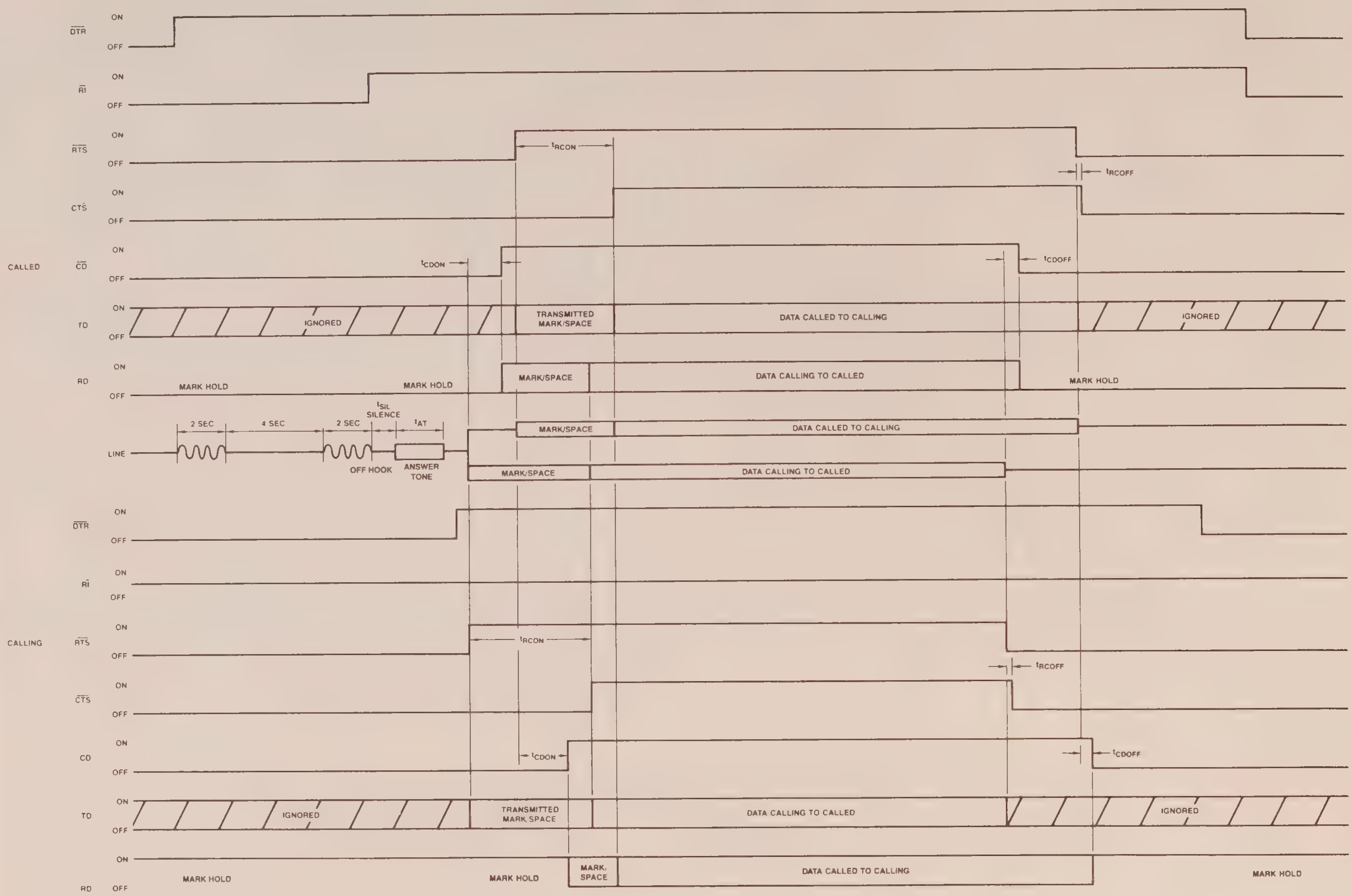


Figure 12. BELL 103/CCITT V.21 handshake timing

MMC-047

CLOCK GENERATION

Master timing of the modem is provided by either a crystal connected to the $XTAL_1$ and $XTAL_2$ inputs or a TTL-level clock inserted into the $XTAL_1$ input.

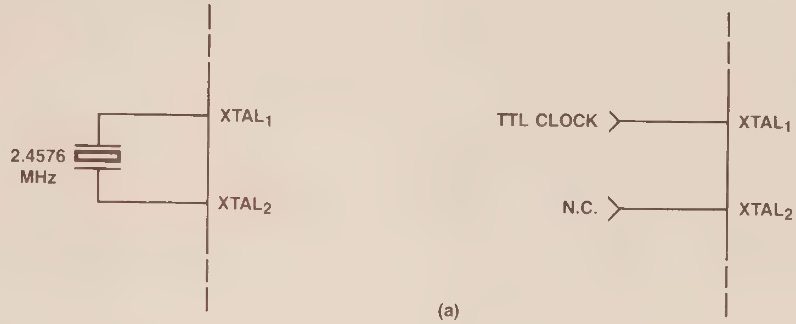
Crystal

When a crystal is used it should be connected as shown in Figure 13. Its value must be 2.4576MHz ±1%.

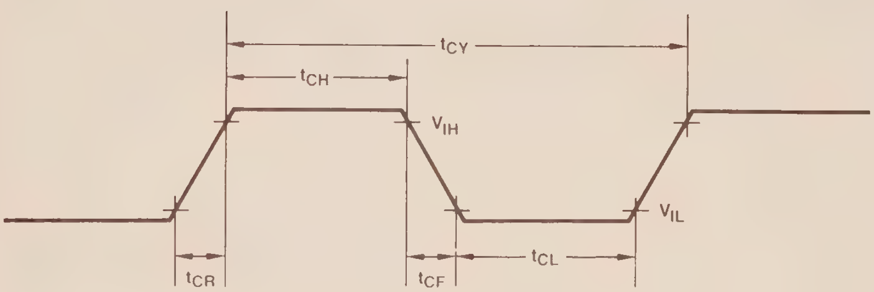
TTL Clock

This clock signal could be derived from one of several crystal-driven baud rate generators. It should be connected to the $XTAL_1$ input and the $XTAL_2$ input should be left floating. The timing parameters required of this clock are shown in Figure 13 and the values are listed in Table 4.

Crystals:
Crystek, CY2B — 32 pf
U.S.C.C. 2.4576 MHz



(a)



(b)

Figure 13. Clock Generation

MMC-048

TABLE 4
TTL Clock Parameters

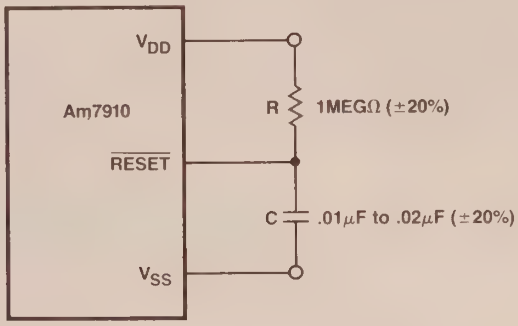
Symbol	Parameters	Min	Typ	Max	Units
t_{CY}	Clock Period	403	407	411	ns
t_{CH}	Clock High Time	165			ns
t_{CL}	Clock Low Time	165			ns
t_{CR}	Clock Rise Time			20	ns
t_{CF}	Clock Fall Time			20	ns

POWER ON RESET

The reset circuit operates in either of two modes.

Automatic Reset at Power On

In this mode an internal reset sequence is automatically entered when power is applied to the device. One resistor and one capacitor must be connected externally as shown in Figure 14.

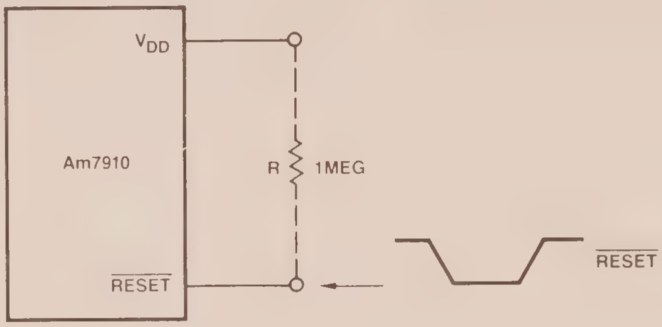


MMC-049

Figure 14. Automatic Power On Reset

EXTERNAL RESET

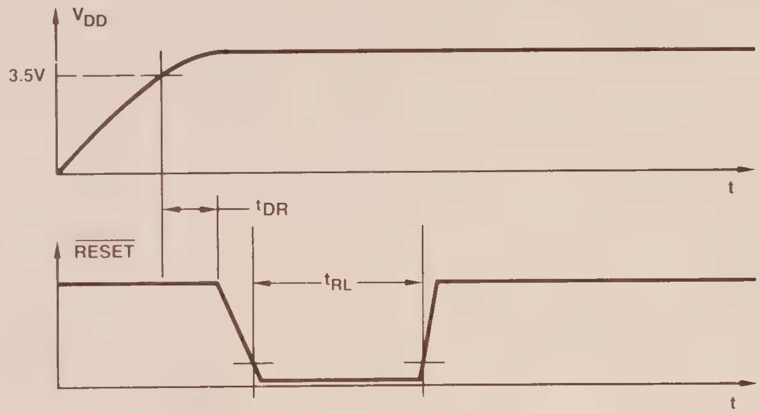
In this mode the device may be forced into the reset sequence by application of an active LOW TTL pulse applied to the $\overline{\text{RESET}}$ input. One resistor can be externally connected as in Figure 15(a), but it is not required. Timing is diagrammed in Figure 15(b).



(a)

MMC-050

TIMING DIAGRAMS



t_{DR} = delay from the time V_{DD} reaches 3.5V and the falling edge of $\overline{\text{RESET}}$ signal (>1μs)
t_{RL} = $\overline{\text{RESET}}$ Low duration time (>t_{MCK})

(b)

MMC-051

Figure 15. External Power On Reset

PERFORMANCE SPECIFICATIONS
TRANSMITTER

Modulation technique: Binary, phase-continuous FSK
Input Data Format: Serial, binary, asynchronous
Frequency Synthesizer:
  Frequencies accurate to within 1.0Hz
  Harmonics: −45dB from fundamental for single tones

Output Level: .77VRMS into 600Ω (0dBm)

Maximum delay uncertainty from digital data change at TRANSMITTED DATA input to TRANSMITTED CARRIER frequency change: 8.3μs

Single transmitter
Out-of-band energy: See Figure 16

RECEIVER

Demodulation Technique: Differential FM Detection
Sensitivity at receiver input: 0dBm to −48dBm
Peak Intersymbol Distortion: 10% back-to-back over input
  (Isochronous ± Bias) signal range 0 to −42 dBm; 511-bit test pattern

Bit Error Rate (BER): See Figures 18-23
Mark/space frequency variation tolerance: ±16Hz
Fixed, Compromise Equalizer available for 202 and V.23 modes
Carrier Detect Threshold
  ON when receiver input ≥ −43dBm
  OFF when receiver input ≤ −48dBm

Single Receiver
Impulse Noise Sensitivity: See Table 5
Amplitude Hit Sensitivity (including line dropouts): See Table 5

TEST MEASUREMENT SETUP

Am7910 performance is characterized using the test equipment configuration shown in Figure 17. The HP 1645S Data Communications Test Set is used to generate digital data test patterns (e.g. 511-bit random) and to measure distortion and bit error rate. A Wandel and Goltermann TLN-1, a W and G DLZ-4, and a Bradley 2A can simulate numerous phone line conditions. The TLN-1 and DLZ-4 simulate amplitude and group delay. Line perturbations such as amplitude hits, phase hits, impulse noise and random noise can be injected by the Bradley 2A. A summing amplifier adds the local Am7910 transmitter signal to the received signal. By varying the amplitude of this transmitter signal, the effect of duplexor rejection can be simulated. The HP 3551 Transmission Test Set measures signal and noise levels. Noise is measured with C-message weighting.

TEST RESULTS

Figures 18-23 depict typical bit error rate (BER) vs. signal-to-noise ratios (SNR) for various modem configurations and line conditions. Total distortion is also indicated on these plots. Table 5 lists typical results for the line perturbations impulse noise, amplitude hits, and line cutouts.

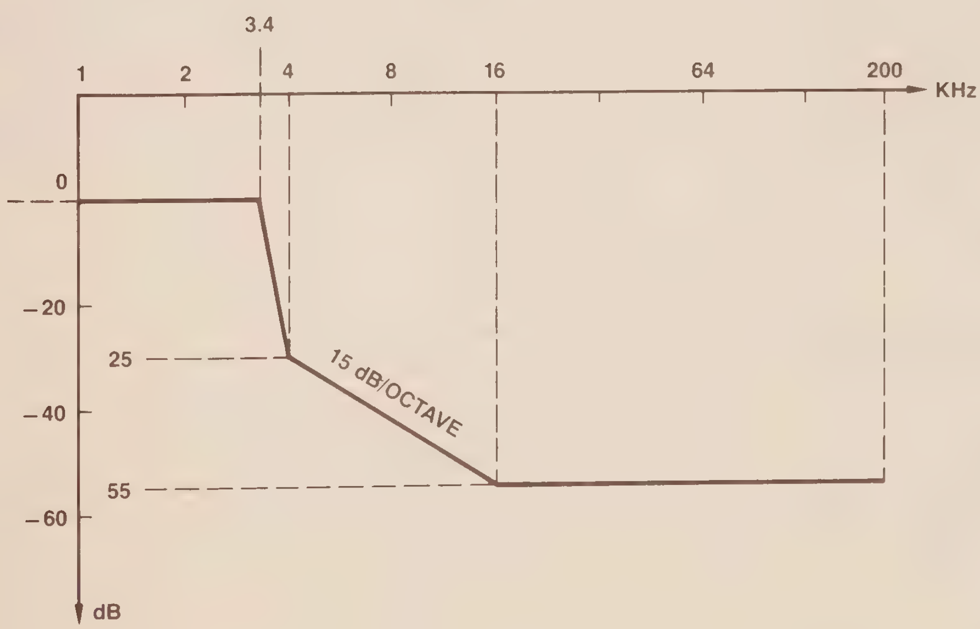


Figure 16. Out of Band Transmitter Energy

MMC-052

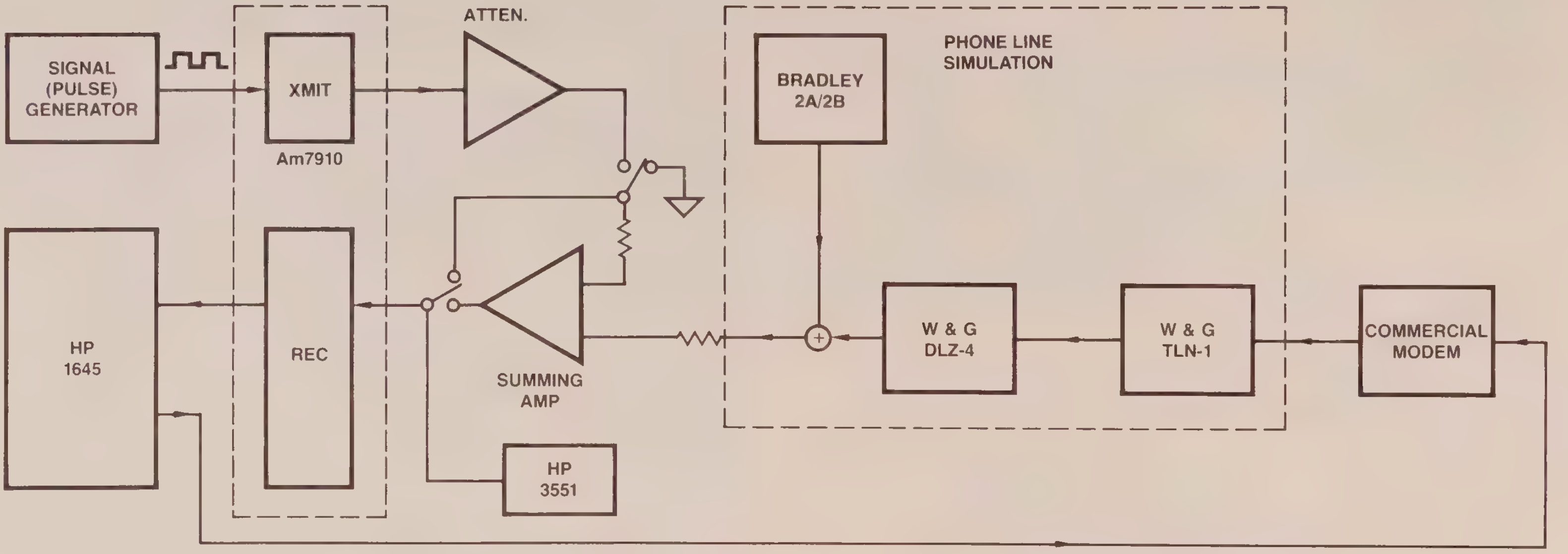


Figure 17. Test Measurement Setup

MMC-053

PERFORMANCE CURVES

V.23, 1200bps BER versus SNR, Different Lines

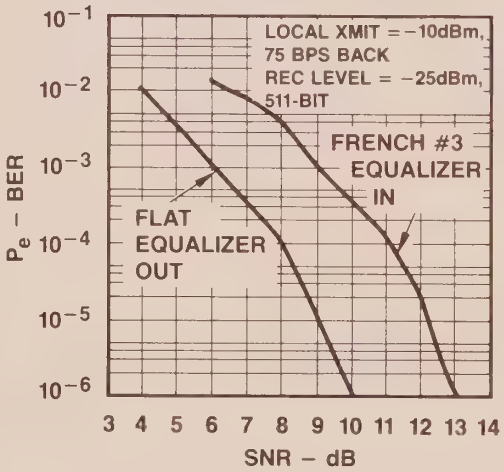


Figure 18.

V.23, 1200bps BER versus SNR, Flat Line, Different Levels

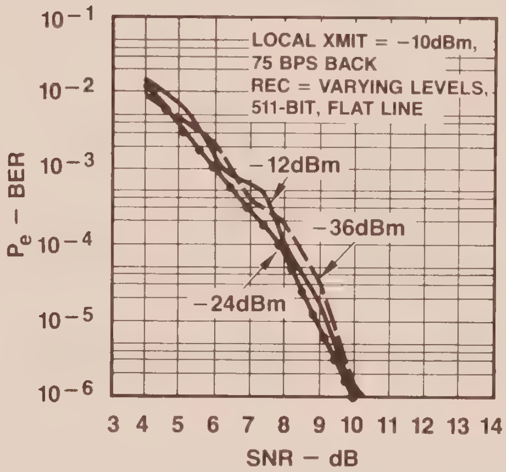


Figure 19.

V.21 ORIG, 300bps BER versus SNR, Different Levels

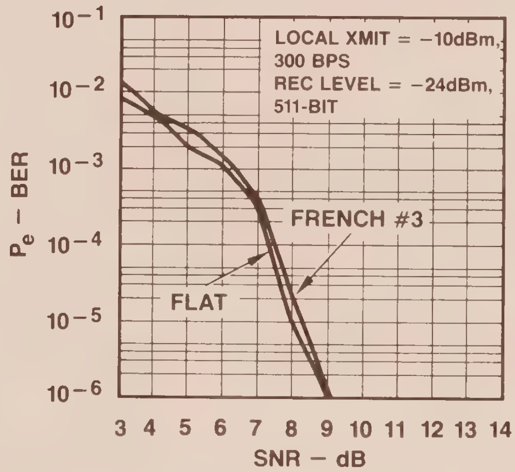


Figure 20.

103 ORIG, 300bps BER versus SNR, Different Lines

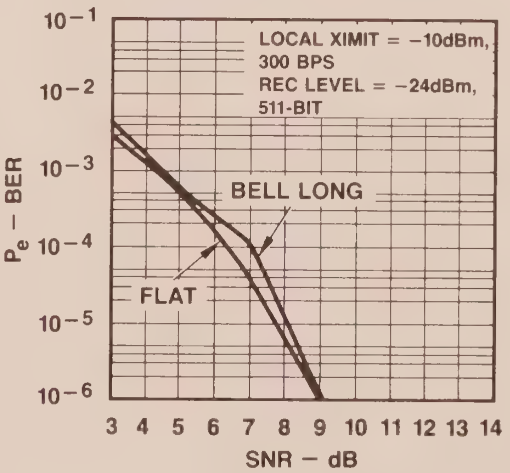


Figure 21.

202, 1200bps BER versus SNR, Different Lines

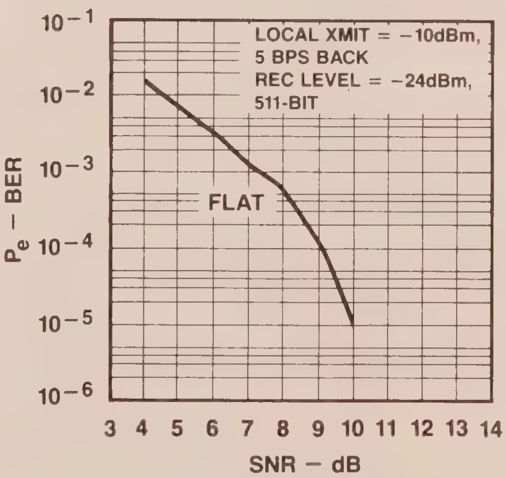


Figure 22.

202, 1200bps BER versus SNR, Flat Line, Different Levels

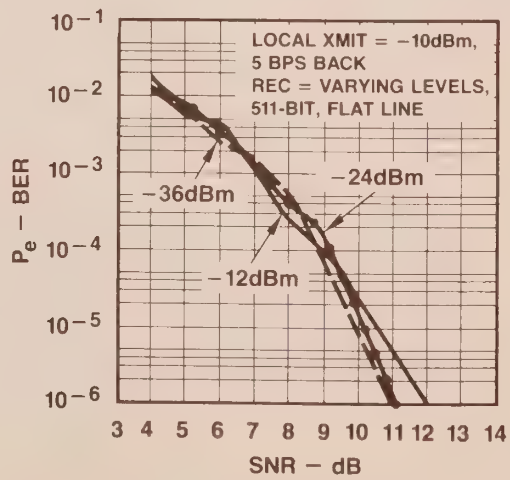


Figure 23.

MMC-054

TABLE 5

RESISTANCE TO IMPULSE NOISE:

Reception signal level: −24dBm

S/N ratio: −3dB (noise pulse amplitude: .2V_{CC})

An impulse noise (bipolar pulse) occurs every 10ms

The typical bit error rate, corresponding modem and impulse width:

Modem Type / Impulse Width	Bell 103 Orig	Bell 103 Ans	CCITT V.21 Orig	CCITT V.21 Ans	CCITT V.23 Mode 1	CCITT V.23 Mode 2	Bell 202
100 μs							
200 μs							

RESISTANCE TO AMPLITUDE JUMPS (HITS):

Reception level: −25dBm

t_{ON} = 1 sec t_{OFF} = 1 sec

Typical error count:

Modem / Atten	Bell 103 Orig	Bell 103 Ans	CCITT V.21 Orig	CCITT V.21 Ans	CCITT V.23 Mode 1	CCITT V.23 Mode 2	Bell 202
1dB							
4dB							
9dB							
14dB							

RESISTANCE TO LINE CUTOUTS:

Reception level: −25dBm

Typical error count:

Modem / Amount of Line Cutout	Bell 103 Orig	Bell 103 Ans	CCITT V.21 Orig	CCITT V.21 Ans	CCITT V.23 Mode 1	CCITT V.23 Mode 2	Bell 202
100μs/3sec							
1ms/3sec							
5ms/sec							

MAXIMUM RATINGS beyond which useful life may be impaired

Storage Temperature	−65 to +125°C
Ambient Temperature Under Bias	−55 to +125°C
V_{BB} with Respect to V_{DGND}	−7 Volts/+.4V
V_{DD} with Respect to V_{DGND}	+7 Volts/−.4V
All Signal Voltages with Respect to V_{DGND}	±5 Volts

OPERATING RANGE

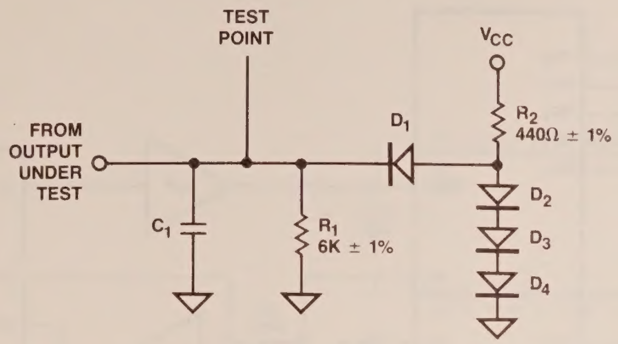
Ambient Temperature	V_{BB}	V_{DD}	V_{AG}	V_{DGND}
$0°C \leq T_A \leq +70°C$	−5.0V ±5%	+5.0V ±5%	0V	0V

ELECTRICAL DC CHARACTERISTICS over operating range, referred to V_{DGND}

Digital Inputs: TD, $\overline{RTS}$, MC_0-MC_4, $\overline{DTR}$, $\overline{RING}$, BTD, $\overline{BRTS}$, $XTAL_1$
Digital Outputs: RD, $\overline{CTS}$, $\overline{CD}$, BRD, $\overline{BCTS}$, $\overline{BCD}$

Parameters	Description	Test Conditions	Min	Typ	Max	Unit
V_{OH}	Output High Voltage	$I_{OH} = -50\mu A$, $C_{LD} = 50pF$	2.4			Volts
V_{OL}	Output Low Voltage	$I_{OL} = +2mA$, $C_{LD} = 50pF$			0.4	Volts
V_{IH}	Input High Voltage		2.0		V_{DD}	Volts
V_{IL}	Input Low Voltage		−0.5		0.8	Volts
I_{IL}	Input Leakage Current	$0.0 \leq V_{IN} \leq V_{DD}$			±10	μA
I_{OL}	Output Leakage Current	$0.0 \leq V_{IN} \leq V_{DD}$			±10	μA
I_{BB}	V_{BB} Supply Current				25	mA
I_{DD}	V_{DD} Supply Current				125	mA
CO	Output Capacitance	$f_C = 1.0MHz$		5	15	pF
CI	Input Capacitance	$f_C = 1.0MHz$		5	15	pF
Analog Input (RC):						
Z_{IN}	Input Impedance	$-1.6V < V_{RC} < 1.6V$	50			Kohms
V_{RC}	Operating Input Signal		−1.6		+1.6	V
V_{RCOS}	Allowed DC Input Offset		−30		30	mV
Analog Output (TC):						
Z_{OUT}	Output Impedance	$-1.1V < V_{TC} < 1.1V$			20	Ohms
I_{OUT}	Useful Output Current	$R_L = 600\Omega$	1.3			mA (RMS)
V_{TC}	Output Voltage Swing		−1.1		1.1	V
V_{TCOS}	Output DC Offset		−200		200	mV

STANDARD LOAD CIRCUIT



Notes:
1. C_1 = 50pF including stray and wiring capacitance
2. All diodes are IN3064 or equivalent
3. All resistors are 1/8 watt
4. V_{CC} = 5 volts ±1%

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APPLICATIONS

Figure 24 depicts a stand-alone Am7910 configuration. An op amp and three resistors provide a duplexor function to put the transmitter output onto the line while receiveing adjacent channel data from the line. Connection to the line is via a Data Access Arrangement (DAA). Note the lack of external analog filters. The TTL handshake signals may be level converted to RS-232, RS-422, or V.24 using appropriate devices. Mode control lines are hardwired or connected to switches.

Figure 25 depicts use of the Am7910 when a microprocessor resides in the same physical location. The duplexor/line interface is identical to the above configuration. However, the handshake signals interface directly to a UART-type device which in turn interfaces to a microprocessor. The mode control lines might also be controlled by the microprocessor.

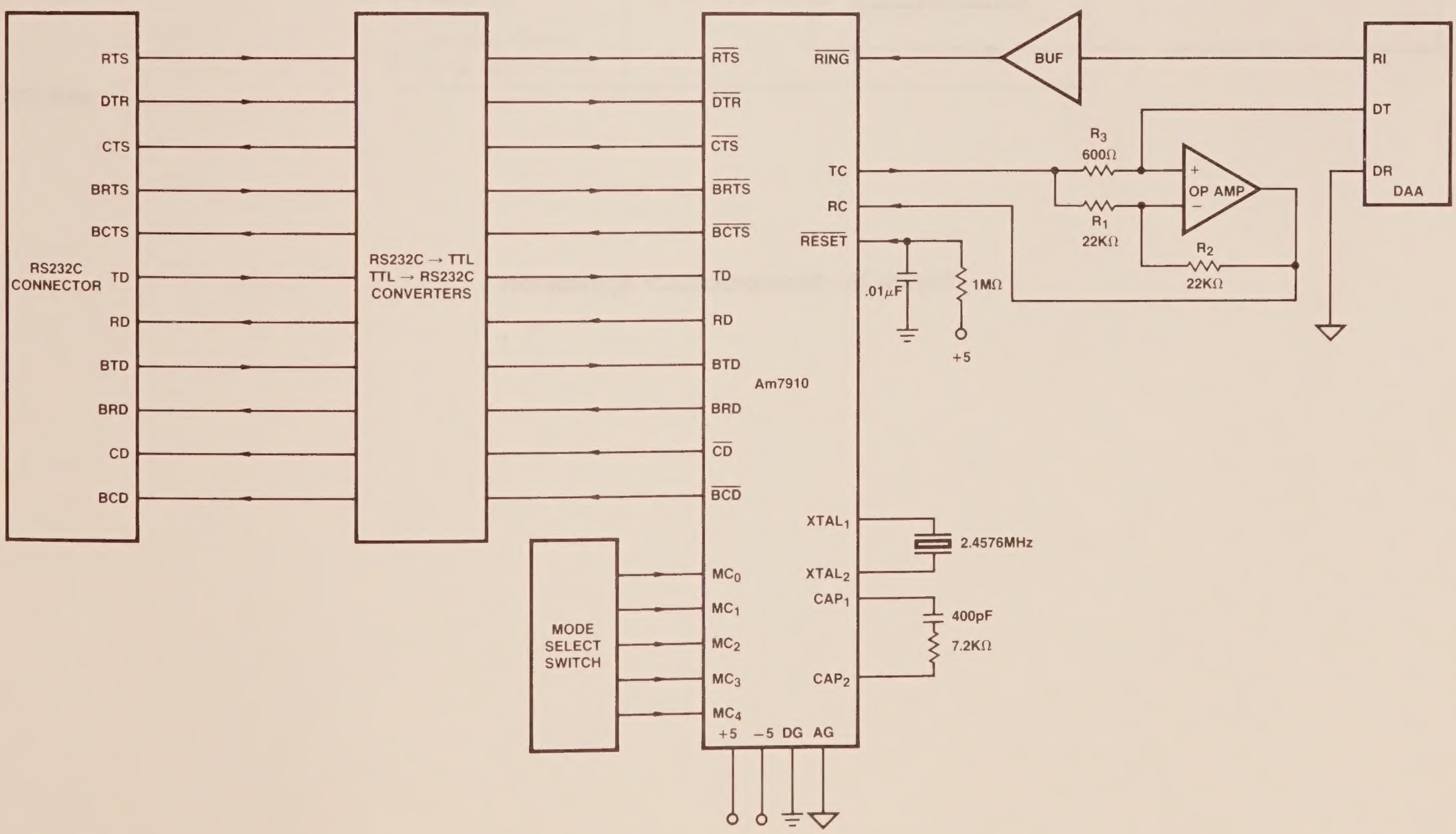


Figure 24. Stand-Alone Am7910 Application

MMC-056

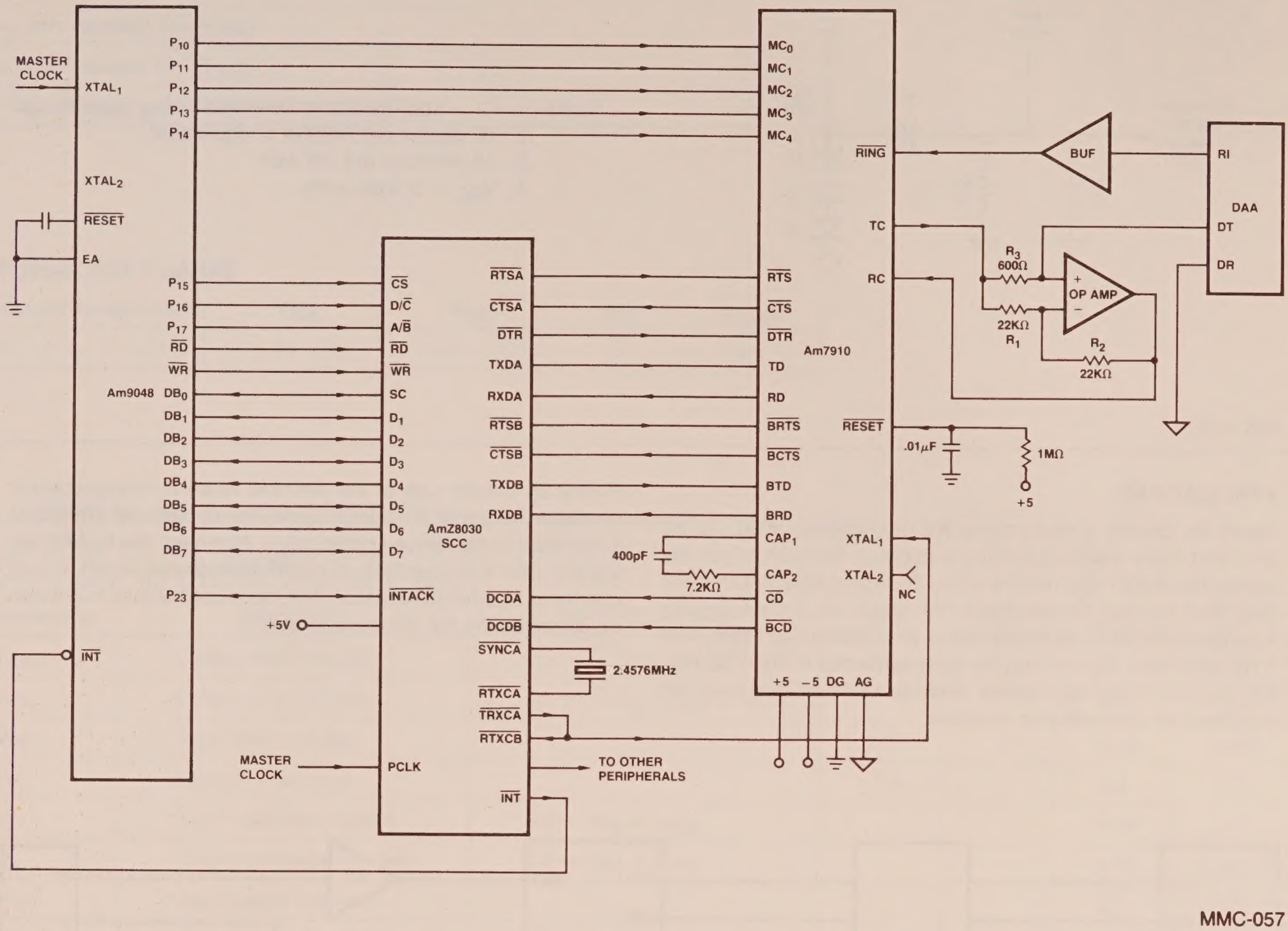
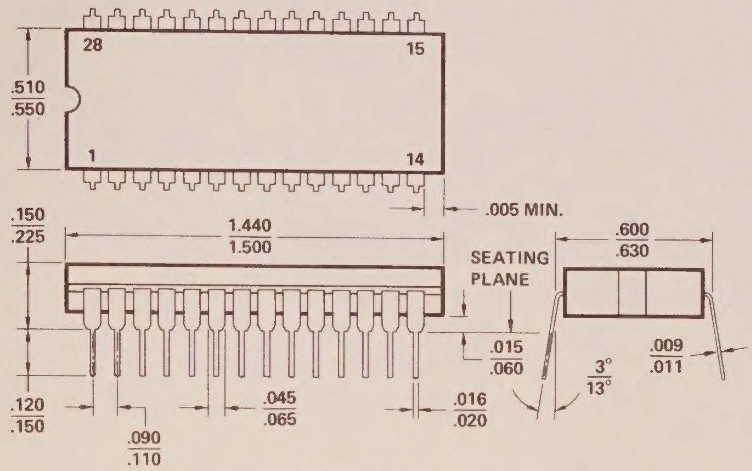


Figure 25. Microprocessor Application

PHYSICAL DIMENSIONS
Dual-In-Line

28-Pin Cerdip



ORDERING INFORMATION

Package Type	Temperature Range	Order Number
Cerdip	$0° \leq T_A \leq +70°C$	Am7910DC
Plastic DIP		Am7910PC
Leadless Carrier (to be announced)		Am7910LC

The International Standard of Quality guarantees these electrical AQLs on all parameters over the operating temperature range: 0.1% on MOS RAMs & ROMs; 0.2% on Bipolar Logic & Interface; 0.3% on Linear, LSI Logic & other memories.

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